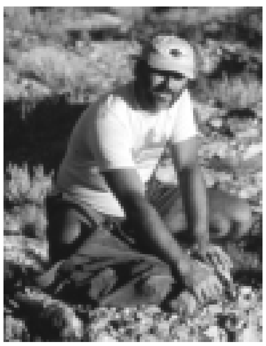
A Second Life
for Trees in Lakes

Michael A. Bozek

As Useful in Water as They Were on Land

Ten thousand years ago, a tree grew near a lakeshore somewhere in North America. For 140 years or more, fish swam in its shade and insects hatched on its branches and leaves; some were eaten by birds, some fell into the water to be eaten by fish, some survived to continue the cycle of life. Birds nested and foraged in its branches, perhaps kingfishers dropped like rocks, propelled by gravity to their next meal; eagles perched among its highest branches. A wood frog chorus would start each evening in spring near the first crotch, and often red squirrels would chatter for whatever reason red squirrels chatter. Then one day it happened: after years of increasing decay near the end of its life, the tree snapped at the butt during a windstorm, and fell with a thunderous crash into the lake; 140 years of silence and quiet rustling, punctuated by a single quick loud finale. Within a minute, the waves that had acknowledged the tree's entry into the water subsided, and all was quiet again.



The tree had lived a full and accomplished life. It had crossed paths with countless generations and species of organisms that used or relied on the structural characteristics of its bole (trunk) and branches or functional processes to carry on with their own life, changing with seasons, changing with age. Yet now, it began its second life . . . in the lake. Within hours, crayfish crawled beneath its partially submerged trunk, to be followed by a mudpuppy and tadpoles, while minnows and small fish hovered within the lattice of its branches. Within days, logperch, darters, sunfish, bass, burbot, pike, and even walleye and muskellunge had also entered the complex network of the newly established community. Algae and diatoms began establishing colonies, while dragonfly nymphs and mayflies followed to forage among the branches. A wood duck competed with a softshell turtle for basking space on the bole that once contained its nest site cavity. Herons, green and blue, alternated use as well: a fine place to access the fish below. And use of the tree by a variety of organisms would continue again for much longer than its life on land; remarkably perhaps 300 to 600 years, slowly changing shape over time as it yields to Father Time. Different organisms continue to use the tree until the cellulose had completely been broken down and its chemical constituents had been fully integrated into the web of life in the lake. And even in the remaining shallow depression it left on the lake bottom, leaves and needles of trees still standing, accumulate creating more habitat for aquatic insects. All this and more occurred from a single tree. A habitat as diverse as this, a relationship between flora and fauna, a union of land and water, evolved to perfection over millennia.

For millennia, trees have fallen into lakes and fish have been associated with them. It is no mistake then that among numerous paleontological sites of ancient lakes that I study in the western United States, some as old as 65 million years, I often find fossils of trees and fish together, remnants of ancient littoral zones. Early pike (*Esox tiemani*) and eight other species of fish are found among leaves and branches of numerous species of trees including the now extinct Ginkgo trees in an ancient lake in western North Dakota. In Wyoming, palm fronds and other trees are found among mass mortalities of ancient herring and a community of other fish species preserved together in stone. And even today, a plethora of species still can be found between the bole and branches of submerged trees in lakes. This evidence clearly underscores the long-lasting relationship between aquatic and riparian ecosystems, between trees and fish, perhaps as long as both have existed on earth.

The structural and functional linkage between littoral zones and riparian areas is forged by the concomitant juxtaposition of the land-water interface. Trees in riparian areas grow, mature, and fall into lakes; seedlings mature and replace older trees, thus continuing the cycle. Throughout time, this union has been interrupted only occasionally by some large-scale catastrophic event: a fire, windstorm, or perhaps even some volcanic eruption such as witnessed at Mount St. Helens in Washington eliminating trees and precluding any recruitment into aquatic systems. Despite the size and extent of these large-scale events, they all have one thing in common: nature recovers if given the opportunity. Ecosystems are resilient; they bounce back. Some slopes of Mt. St. Helens, for instance, have revegetated by natural processes. Similarly, riparian areas of lakes and streams burned in 1987 in Yellowstone National Park now exhibit an abundance

A school of adult smallmouth bass congregate below a remaining old white pine bole in the littoral zone a of a northern Wisconsin lake.

of new young trees, some of which may later fall into lakes and streams to become habitat for aquatic life. Clearly, once riparian areas reestablish, the relationship between trees and fish can continue.

More recently, changes to riparian areas of lakes in north central North America differ from those caused by natural phenomenon: they face man. Man has altered riparian areas of lakes at rapid rates across a large portion of the landscape, first by logging and, more recently, by lakeshore development. However, it is this latter perturbation that is potentially more problematic. In the upper Midwestern United States, forest stands have recovered, more or less, in previously logged areas and now sustain second growth forests. As a result, trees again recruit to lakes through a variety of natural processes and anthropogenic events. In contrast, many riparian landowners along developed shorelines have removed some or all trees both on land and in water, thus eliminating the beneficial uses they provide in natural systems. However, in addition to removing trees, the recovery process also has now been altered by shoreline development. After the initial perturbation where trees are removed, succession is often held in check as many landowners continually manicure their property removing understory trees, seedlings, and saplings. This continual manicuring further delays recovery, perhaps indefinitely until attitudes regarding land use change. Any solutions to managing these types of disturbances that fail to take into account both short-term (i.e., removal of older trees) and long-term (i.e., removal of understory, seedlings, and saplings) processes, will ultimately converge toward the same consequence: no trees.

Large Woody Structure

Trees in lakes are often referred to as “large woody debris”, a misnomer specifically derived from debris torrents in steeper western mountain terrain where debris jams full of soil, sod, shrubs, sticks, twigs, and whole trees collect during a mass wasting event clogging streams and often creating temporary ponds in streams. The term “debris” also connotes something to dispose of and having little value. Because of the value of large wood in both streams and lakes, and because of the aforementioned derivation of the term, “large woody debris” is largely inappropriate. The more appropriate terms should be large woody structure or submerged wood, used herein.

Use of Large Woody Structure by Fish

Fish use submerged trees in a variety of ways. Many species spawn adjacent to or under trees that provide cover that helps them protect their incubating brood. In smallmouth bass and other sunfish, nests adjacent to or under submerged trees reduce the nest perimeter that needs to be defended against predators. Small sticks and twigs are often found in the nests of bluegills; eggs are attached to the sticks keeping them above the bottom where they may be exposed to fungus. Fathead minnows spawn on the underside of wood in cavities. The young of many species of fish are dispersed throughout the branches for protection while predators, such as northern pike and muskellunge, use the same trees for ambush foraging. Shade from branches and the bole provides daytime refuge for diurnal species such as walleye. Use of trees can be species-, age-, and season-dependent but regardless of how different species of fish use trees, trees clearly attract fish.

Our current research shows that the association of fish to trees clearly is related to the complexity of branches and, to a lesser extent, the location and position of the tree in water. More fish and more species of fish use more complex trees and, in fact, individual, large, complex trees host entire fish communities. In north temperate lakes, up to 15 species or more may inhabit a single tree at a time (Table 1). Walleye and white suckers can be found beneath trees in deeper water, adult smallmouth bass can be found beneath the bole, and many of the other species from cyprinids (i.e., minnows), to bluegills, pumpkinseed, rock bass, to muskellunge and more can be found throughout the complex web of branches.

But we need to look beyond single trees to understand how they function in lakes, which in turn, helps foster proper stewardship. For instance, submerged trees located closer to other submerged trees result in even greater numbers and diversity of fish compared to individual trees. Larger numbers of submerged trees create a mosaic of habitats over greater shoreline areas than single trees do. This underscores the importance of riparian areas. We need to manage entire riparian areas that help develop complex littoral zone habitats, not just provide token individual trees that make us feel good. In lakes with depauperate natural habitat features, such as large woody structure, just about any structure, such as cribs, will attract fish. Fish cribs are often built to attract fish for anglers in the guise of "habitat management" and in essence attract both fish and anglers, yet the role of cribs as actual habitat is not well-established. The attraction of fish to a crib can be substantial, provided it is designed correctly. However, natural trees are inherently more complex, providing better habitat than cribs.

Trees differ in their suitability to different species of fish based on architectural differences that change over time and differ among tree species. After falling into a lake, trees decompose and decay, losing their structural complexity. Concurrently, the number of species and the abundance of fish associated with that tree decline. If trees are alive at the time they fall into the lake (and provided it is the right season), they will have leaves or needles intact for a short period of time (usually a season), further increasing their complexity. Over time, they then lose fine branching first, followed by coarser branching, until a simple bole remains; then even the bole, resistant to decay, finally succumbs to decomposition.

Table 1. Fish species found in one submerged white pine tree in Katherine Lake, Wisconsin

• black crappie	• mottled sculpin
• smallmouth bass	• logperch
• largemouth bass	• Johnny darter
• walleye	• yellow perch
• muskellunge	• white sucker
• rock bass	• cyprinids (minnows)*
• bluegill	
• pumpkinseed	

* Cyprinids could represent multiple species but are difficult to visually identify during diving.

Unfortunately, the rate of decay and decomposition relative to its use by fish is not well-studied. There are also differences in the architecture of tree branching, the largest difference occurring between hardwoods and conifers. Conifers tend to have a denser, more compact arrangement of branches, than do hardwoods primarily because their branches extend in concentric whorls.

Habitat Management and Sustainability

Clearly, large woody structure in lakes creates habitat, but it is still not well-understood. One question unanswered is to what extent large woody structure actually increases the abundance of a particular species of fish. This is a fundamental problem in understanding fish habitat in general. "Habitat" is one of those words that is supposed to make people feel good. Use the term among anglers at a fish club meeting and you can see members grinning and nodding with satisfaction as the general concept of habitat is something everyone can relate to and agree on. Habitat is good. In fact, it is as good and wholesome as mothers and apple pie. Moreover, the person mentioning habitat among his peers instantly elevates his stature just simply by invoking the term.

However, understanding habitat and managing habitat is far from simple. Why is that? It probably results because the word habitat invokes a wide variety of images among lay people and biologists alike and because a conceptual basis for understanding and quantitative research on habitat is lacking. Habitat in lakes could be any or all of the following: rock bars, macrophytes, a series of docks along a lakeshore, fish cribs placed by management agencies, rip-rap shorelines, sunken Christmas trees, sunken boats, etc. In fact, just about anything ever naturally occurring in lakes or placed in them by people can be construed as habitat by someone for some species. In extreme cases, power companies propose building reefs in the Great Lakes with waste material from coal-fired power plants that increase their profitability because of the ease at which this material can be barged and "dumped". Yet, this material is so heavily laden with an alphabet soup of toxic chemicals from arsenic to zinc and nearly every nasty element in the periodic chart in between that it would constitute a superfund site were it not for political verbal Gerrymandering that allows people and agencies to fondly refer to this as "habitat. . . . " "Well, if it walks like a duck. . . . " Oil companies abandon offshore oil rigs that are so readily deemed habitat that one wonders how oceanic fish ever survived and evolved since the Devonian Period 420 million years ago without them. Used tires, more commonly used in the southern U.S., are "habitat" and clearly can be readily had and placed into lakes. The list goes on. Attracting fish and creating habitat are two very different things. The later requires evidence beyond mere association of fish with an object.

The variation in conceptualizing habitat results largely from biases that arise from different life experiences among people or different training among biologists as well as the selfish self-interest of people and corporations. One person's excellent panfish macrophyte bed is of less interest as habitat by smallmouth bass anglers, just as the reverse may be true for late summer mid-water rock humps. Quickly a dilemma arises: what habitat do we manage for when two different people view habitat differently, depending on their self-interests and value systems? Taken to the extreme, with unlimited funds, we actually can (i.e., we have the ability to) restructure entire littoral zones of lakes. Already, lake management groups and agencies try to remediate habitat limitations by placing aerators in lakes, draw down water bodies to compact sediments in millponds, allow macrophyte control by a variety of methods, etc. But the question remains, how should we design or restore the littoral zone?

Because our perceptions vary among people and value systems, the only sure guide we have is to look at how habitat is created naturally under the conditions in which natural systems evolved with fish and allow natural processes to structure it again. Since fish evolved with natural terrestrial and aquatic processes at absolutely no cost to anyone for millennia, doesn't it make sense to facilitate the natural processes in these systems? Who can argue with that long-term track record of success? Clearly, this would be the most cost-effective long-term management strategy, certainly until we have more answers.

Recruitment Dynamics of Trees

Large woody structure is most abundant in smaller lakes with undeveloped shorelines. The rate and pattern in which wood recruits into lakes depends upon the stand dynamics of trees in the riparian area including age, species, site conditions, and stage of succession. This process can be referred to as a recruitment cycle: trees grow in the riparian area, mature, and then fall into the lake. Seedlings develop into saplings and then mature trees, which in turn, continue the recruitment process via succession. Other factors aside, such as disease, extreme weather, fire, etc., mixed-age (i.e., uneven-age) stands would tend to recruit wood periodically in some random fashion depending upon the species present and age of individual trees in the stand. In contrast, even-age stands would recruit in a pulsed fashion; early in the stand age, tree recruitment would be negligible but as the overall stand matures, trees would recruit to the lake at a greater rate.

Either episodic natural events or perturbations caused by human activity can interrupt the recruitment cycles. In extreme cases, recruitment rates of trees into lakes are interrupted by catastrophic events such as fire, extreme weather, disease, etc. that can modify riparian vegetation quickly. The immediate consequences are determined by specific properties of the structuring events. For instance, high straight-line winds or tornadoes can blow trees down: trees on the windward shore may blow onto land, whereas on the lateral or leeward side of the wind, entire shorelines can have trees blown into the water. The patchy pattern of fires determines which portions of riparian areas burn and which survive.

Humans also alter the abundance and distribution of wood into lakes. Fire and logging riparian areas eliminate trees, thus affecting long-term recruitment rates. For instance, Guyette and Cole (1999) found that no trees had entered Swan Lake, Ontario since being logged around the turn of the century. However, succession in the riparian area has allowed trees to grow back and the recruitment process will resume in time, bar any additional setbacks. The interval between the structuring event and recovery clearly depends upon stand dynamics.

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However, the most far-reaching perturbation to the natural recruitment cycle is the development of shoreline properties (i.e., houses and activities) combined with the incessant artificial over-manicuring of riparian areas and direct modifications done to littoral zones. Future forest stand composition in the riparian area depends on succession dynamics of younger trees in the understory that carry the recruitment process into the future. Without it, there is no potential for future recruitment. Christensen et al. (1996) found that humans greatly influenced the abundance of trees in littoral zones of lakes. In their study of undeveloped lakes in northern Wisconsin and the upper peninsula of Michigan, they found that in lakes with no development, forested shorelines averaged 555 logs/km of shoreline. On developed lakes, undeveloped shorelines contained an average of 379 logs/km of shoreline versus just 57 logs/km along shorelines where cabins (i.e., houses to mansions) have been built. Jennings et al. (1999) showed that levels of wood in littoral zones of lakes that had more advanced shoreline perturbations (i.e., having seawalls and rip-rap) was reduced, apparently due to direct removal by riparian landowners interested in having an uncluttered shoreline. But it is the loss of seedlings that delay recovery and sustain the perturbation with the "golf course lawns" being the most extreme case.

Another purpose of forested riparian areas is that they buffer lakes and streams from contaminants transported during runoff, particularly from developed watersheds. Ironically, not only have these areas been eliminated where forested riparian areas have been replaced by lawns, often the pesticides and fertilizers added to these artificial environments, exacerbates transport to lakes. In short, we removed the vegetated buffer and on top of that, we've added more pollutants. This role of intact riparian benefits has been well-studied and need not be examined here in more detail.

Habitat Remediation for Wood in Lakes

After extolling the virtues of trees in lakes as habitat, it is necessary to caution against remediating treeless littoral zones by directly felling trees as an enhancement technique unless the short-term needs are so extreme as to warrant such measures (e.g., endangered fish habitat). Short-term fixes, albeit well-intentioned, often have long-term consequences that need to be fully explored. In a previous job that I once held for an agency in the western United States, I was told that I needed to fell a prescribed number of trees per mile to enhance steelhead and Chinook salmon habitat in streams. Initially, we felled trees into the rivers and cabled them to stumps. This anchored them in place to increase the length of time they would be "habitat" for fish. In the short term, we enhanced tree recruitment in excess of the natural rate of recruitment, but over the long haul, we in essence, stole those trees from the future. This is not unlike the debate about the budget deficit. We benefit from current programs by overspending revenues that have consequences for future generations; now future generations must pay for our programs plus theirs. Clearly, more sustainable solutions are needed. Riparian areas are inextricably linked to littoral zones. No riparian trees means that one source of one component of littoral zone habitat is eliminated into the future. It is this gray area of resource management where private property rights (riparian management) can conflict with management of public resources (littoral zones) that makes managing trees controversial. Perhaps buying property shouldn't necessarily mean doing with it as we please. Rather, ownership should confer with it the responsibility of managing it properly for the lake ecosystem. By default, the position of riparian land elevates the owner to a higher level of responsibility as changes have consequences for the lake as a whole.

Perhaps it's time to revisit Aldo Leopold's land ethic and apply it to managing riparian areas of lakes. Wise management of large woody structure requires we protect both the sources and fate of trees. For fish biologists, taking the lead in helping people restore riparian areas rather than just focus directly on fish in lakes is paramount, but this will require long-range planning and commitments. While the benefits may take generations to be realized, the earlier we start, the sooner we can benefit from reestablishing natural vegetation to riparian areas. Isn't it ironic, that on many lakes, we have reduced or eliminated trees in riparian areas thus preventing their recruitment as habitat into lakes, only to then build fish cribs made of trees at substantial additional cost? Pure craziness.

Riparian vegetation is a "free commodity" provided by nature. All we need to do is recognize its benefits and utilize its full potential. Unfortunately, our unwillingness to use this source of free habitat says a lot about our generation. We must first change our perception of which shoreline features are healthy, and thus desirable, and accept the look of "natural" shorelines as the first step toward restoring littoral zone habitats. Are we willing to plan to improve the future without necessarily being able to immediately reap the rewards of proper stewardship? A tough sell perhaps, but its time has come. For 420 million years fish and forests have evolved together, yet only in the past 100 have we interrupted or in some cases, eliminated that cycle out of our ignorance, neglect, or arrogance. If we think hard about the virtues of sustainability, hopefully the course of action will be second nature.

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Michael Bozek *is the Research Unit Leader at the Wisconsin Cooperative Fishery Research Unit located at University of Wisconsin–Stevens Point (Stevens Point, WI 54481, email: <michael.bozek@ uwsp.edu>). He has worked in fish-forest relations in the lakes and streams of Wisconsin, Ontario, Wyoming, and Idaho.* X